INHERITANCE OF CHLOROPHYLL AND COTYLEDON COLOR IN SOYBEANS

BY

PAO HUA LIU

B.S., National Central University, China, 1940
M.S., National Central University, China, 1944

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRONOMY
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1950

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This study has been carried on with materials which were kindly furnished by Professor C. M. Woodworth. All crosses were made by the writer. The record on chlorophyll was taken at various stages on vegatative growth in the plants. Records on color of cotyledon, pod, and seed coat were taken on the mature plants. Leaves were sectioned by free hand for anatomical study, mounted in 50% glycerine and immediately examined under the microscope. Woodworth's formula (1923) and Immer's product method and tables (1930) were used for the analysis of linkage.

I. Anatomical Study Of Leaves

A. Normal green types

Green and yellow pigments in soybeans, as in all plants, are contained in special structures called chloroplasts. In the normal green plant, Chimera, T38, and T104, the chloroplasts range from 7.5 to 8.5 microns in their longest diameters. The writer was not able to detect any chloroplast difference in the leaves between the cytoplasmic green cotyledon type (T104) and genetic green cotyledon types (T38, Chimera). All of these normal green types seem to have similar chloroplasts, with about the same size, shape, and color.

B. Yellow types

T102. The chloroplasts are rather few in number but to compensate for this they reach giant volume. They are green in sponge tissues and greenish yellow in palisade tissues.

T116. The chloroplasts are of slightly smaller size than those in normal green leaves, but their number per cell is about normal. They are yellow in first upper layer of palisade cells and green in other cells.

T134. The chloroplasts in palisade tissues are slightly smaller than those in T116. No color difference between chloroplasts in T134 and T116 was found.

T135. The chloroplasts in young leaves are normal in size, distribution, and number. They are bright yellow in palisade tissues but green in sponge tissues. The chloroplasts in full-grown leaves are slightly reduced in size but almost all of them change to green in the palisade cells.

T139. In young leaves chloroplasts are almost normal in size, color, distribution, and number. In full-grown leaves their size is greatly reduced, and their color in the palisade cells becomes a deep yellow. In sponge tissues, though the chloroplasts are degenerated into very small size and irregular shape, most of them still retain their green color. This indicates that the full-grown T139 plant is still able to carry on photosynthesis.

C. Pale green types

T136. This type contains well-developed, normal-looking, and numerous chloroplasts which are slightly paler in the first layer of the palisade tissues than the normal ones.

T160. The chloroplasts seem to be a little smaller than those in T136, but are likewise paler in the first layer of the palisade tissues than the normal ones.

D. Variegated type

T144. Chloroplasts in the variegated leaves are extremely irregular in shape and size, being large, small, and degenerating bodies. Chloroplasts of the greeen regions are entirely normal. Chloroplasts of the white region are much smaller in size, fewer, and paler in color than they are in the green region.

II. Inheritance Of The Chlorophyll-Deficient Types

A. Yellow types

T102. Leaves are greenish yellow in the seedling stage, and turn more yellow after the early flowering stage. Different areas in the leaf are of varying chlorophyll intensities. When the seeds start to form, the leaves become more greenish, but change gradually and very slowly, until, at the full-grown stage, all leaves have become pale green except for tiny yellowish-green spots on the under surfaces. When T102 was crossed with normal green types, other yellow types and pale green types, almost all the F_1 plants showed very marked hybrid vigor, and the F_2 results showed good fit for the expected phenotypic ratios. The gene carried by T102 is a simple recessive to the normal green and was designated y_4 by Woodworth and Williams (1938).

T116. This is a very weak type. The plant is only about 10 inches high. Leaves are yellowish green in the seedling stage and become more uniformly yellowish later on. When the seeds start to form, leaves become more greenish except along their veins. Based on the results of intercrossing of yellow types, one recessive gene, y_5, is thought to be involved in T116.

T134. This is another very weak yellow type. T134 behaves like T116 but seems to be a little stronger. It is about 15 inches high. It was proved that one yellow gene is contained in T134. An important observation is that all plants in the F_1 and F_2 generations of T116 $\times$ 134 were greenish yellow. This is evidence that T134 and T116 possess the same gene, y_5.

T135. This type has distinct, bright yellow leaves from the seedling stage through the flowering stage. After that, the sepals and stems become more yellow. When the seed begins to develop, the leaves start to turn greenish, beginning at the lower portion. Just prior to maturity, the

leaves turn to almost normal green. T135 was crossed with all the types studied in this investigation. Results show that one gene, y_{10}, is carried by T135.

T139. During the seedling and flowering stages, almost all the leaves are normal green, except that 2 to 5 leaves have a few small deep yellow spots on the tips. Leaves, stems, and pods become progressively more yellow until several weeks before maturity, when the whole plant is deep yellow but the leaves still fresh. It was confirmed that T139 carries duplicate recessive genes y_2y_3 for yellowing.

B. Pale green types

T136. This type is pale green in seedling stage but gradually becomes nearly normal green. It apparently develops more green than any other of the chlorophyll-deficient types. It is assumed from genetic evidence presented that duplicate recessive genes for pale green, designated pg_1 and pg_2, are involved in T136.

T160. This type has normal green leaves in the early seedling stage. The leaves turn to pale green from the late seedling stage. From test crosses, there is evidence that two additional recessive genes, designated pg_3 and pg_4, are involved in T160.

C. Variegated type

T144. This type has normal green leaves in the seedling stage. Later on, about the flowering stage, the chlorophyll content of a few leaves is reduced along the leaf veins. As a result, a yellowish white pattern appears on the surface of such leaves. After 2 or 3 weeks, the yellowish white color gradually disappears. It is confirmed that T144 carries two chlorophyll-deficient genes, namely, one gene, y_8, for yellow and one gene, v_1, for variegation.

III. Inheritance Of Cotyledon Color

The cotyledons in the soybeans are of two colors, yellow and green. Many crosses between yellow cotyledon and genetic green types were made. All results confirmed the presence of duplicate genes for yellow cotyledon color. Extensive data show that T104 is a cytoplasmic green type carrying d_1d_2 on its chromosomes.

IV. Linkage Relationships

Gg, genes for seed coat color, and Ll, genes for pod color, are found to be linked to D_1d_1, one pair of duplicate genes for cotyledon color, with a cross-over percentage of 15 and 40, respectively. Crossing over between Gg and Ll is about 48%. These results indicate that Gg and Ll are located on the opposite ends of the third linkage group.

$Y_{10}y_{10}$ are found to be linked to D_2d_2 with a cross-over percentage of 34. One pair of the duplicate genes $Y_2y_2Y_3y_3$, arbitrarily assumed to be Y_2y_2, is found to be linked to Gg with a cross-over percentage of about 11.

A summary of linkage tests may be given in the form of a chromosome map as follows:

Chromosome Map Of Soybeans Showing Revisions Of Chromosomes I. And III.

a. Chromosome I.

0	t, r_2, de
6	l
13	d_2
38	h
47	y_{10}

b. Chromosomes III.

0	g
11	y_2
13	d_1
48	l

VITA

The writer was born on September 19, 1917, in a village in Lao-Wan, Kaiyu, Hupeh Province, China. His early education was obtained in a rural school of that vicinity. In 1930, he entered the Hupeh Provincial First Middle School in Wuchang, China. In 1936, he was permitted to enter the Agronomy Department of the Natioanl Central University, Nanking, China. After the Japanese Invasion on July 7, 1937, he and his school were forced to migrate to Chungking. From 1938 to 1940, he held a scholarship from his Provincial Government and a grant from the Ministry of Education of China. He was graduated in June, 1940, from that university with the degree of Bachelor of Science. In July, 1940, he accepted a position from the National Agricultural Research Bureau as an assistant technologist in Agronomy, which position he held until he enrolled in the Graduate School of the National Central University in August, 1941. He was graduated in June, 1944, with the degree of Master of Science. By passing the qualifying examinations in July, 1946, he was awarded a fellowship by his Provincial Government for advanced study. He arrived in the United States in February, 1948. Since then, he has been enrolled in the Graduate School of the University of Illinois. He held a University tuition scholarship from the summer of 1948 to June, 1950, and a grant from the State Department of the United States from 1949 to June, 1950.